

# **Factors Influencing Occurrence, Scale, Mobility, Runout, And Morphology Of Mass Movements On The Continental Slope**

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## **LONG-TERM GOAL**

Achieve an improved understanding of the relationships between sedimentation, environment, and the morphology of continental slopes. This goal will be accomplished primarily through investigations within the northern California (Eel River) study area and incorporation of data from around the World. An underlying assumption of our work is that the occurrence and morphology of mass movement features on the continental slope depend upon a combination of characteristics, each of which varies over the region in a consistent manner. The various components of this project are part of a concerted effort between the geotechnical groups at the USGS and Laval University. Their activities are very much interwoven but, for administrative reasons, their respective budgets are identified separately as are the annual reports.

## **OBJECTIVES**

Identify factors that can be mapped regionally and that determine where and how slope failures occur; derive a basis for producing regional maps that indicate relative landslide susceptibility. Model shear strength development with depth and incorporate this model into continental slope stability, post-failure behavior, and bedform processes. Observe and model pore pressure development in continental slopes. Analyze the relationship between seismic intensity, sediment instability and slope processes.

## **APPROACH**

Our research focuses on the factors that lead to variations in the sedimentological and environmental conditions determining slope failure. We develop improved correlations between engineering classifications and strength factors. We measure excess pore water pressures in situ. We simulate sediment accumulation in specially designed cells. Geotechnical properties are related to sediment density state, obtained from detailed logs of downcore variability of sediment density and sound velocity. Using available bathymetry, we construct slope maps. Seismic shaking variations are evaluated probabilistically by seismologists. Driving stresses are balanced against strength variations in a geographic Information System (GIS) to obtain a regional estimate of relative slope stability.

Key individuals, at USGS: Homa Lee, Kevin Orzech, Diane Minasian, Peter Dartnell, and Florence Wong: physical property logs of sediment cores and relations between geotechnical and classification properties, algorithms relating sediment properties, environmental factors, and slope stability within the framework of a GIS; at Laval: Jacques Locat, Jean-Marie Konrad, Éric Boulanger, Priscilla Desgagnés, Francis Martin and Frederic Laurent: detailed geotechnical property measurement, SEM studies, and assessment of compressibility, rheology, and shear strength development.

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## **WORK COMPLETED**

In FY99, we continued our development of a GIS-based approach toward regional assessment of offshore landslides. To expand the applicability of our results, we are conducting a comparative study of the Los Angeles Margin using data obtained by Lee as part of a sediment pollutant transport study. We have prepared maps of the Los Angeles margin that show the distribution of relative slope stability. These studies are valuable because the Los Angeles margin shows a much broader distribution of slope failure features and the set of available data is as extensive as that from the Eel Margin. A paper comparing our methodology as applied to both the Eel and Los Angeles margins was prepared for the International Symposium on Landslides to be held in 2000. We are also developing a more fundamental relationship between landslide occurrence and sediment lithology. In the past we have relied upon surficial sediment density as a measure of lithology. We are expanding our correlations to include engineering classifications that are not impacted by consolidation state.

During FY 99, our field work was concentrated on the East Coast, within the New Jersey Margin area in conjunction with the Marion Dufresne OCEANOGRAPHIC cruise. One USGS scientist (Dianne Minasian) joined a group of three scientists from Laval (P. Desgagnés, P. Côté, and M.-C. Héroux) and a research team led by C. Alexander. The main purpose of the Marion Dufresne cruise was to take Calypso cores (20 to 50m long) in a landslide area within the Hudson Apron. A total of 3 long cores were collected (MD9922-11, 12, and 13), of which one is kept at Laval and is to be shared with the USGS group for various geotechnical tests. All cores were logged, onboard the ship, at 1-cm resolution for density, sound velocity, and magnetic susceptibility.

We are collaborating with Syvitski, Parker, Garcia, Orange, and Locat in recognizing and interpreting migrating sediment waves. We feel that these features are common along continental margins and that they are frequently misinterpreted as submarine landslides. We are developing criteria for recognizing these features and applying numerical and physical models to understand the mechanics of their development.

## **RESULTS**

Classic slope failure features on the Eel Margin are rare even though our methodology shows a high vulnerability to slope failure during seismic loading, indicating either that mass wasting on the Eel Margin takes unexpected forms or that mass wasting is less significant than would be expected. Shallow-seated failures are more common on the Los Angeles Margin. Our methodology shows an even higher vulnerability to slope failure in Los Angeles Margin areas experiencing numerous shallow-seated failures. Our methodology shows promise in terms of delineating the environmental conditions that are conducive to shallow-seated submarine slope failure.

In collaboration with Laval, analyses of reconstituted specimens of Eel river sediment have been subjected to drained cyclic loading. Under conditions comparable to a long series of earthquakes, we have found that the undrained shear strength increases significantly. Although these conclusions are derived from tests on re-constituted sediments, we can now formulate a working hypothesis: seismic strengthening is a significant mechanism for explaining the paucity of shallow landslide features in the Eel Margin.

## **IMPACT/APPLICATION**

Relationships developed in this project show the importance of sediment liquidity index and seabed density profiles in representing the behavior of marine sediment. These values can be used to predict regional slope stability and the rheological behavior of debris flows. This project shows the value of GIS techniques in combining the impact of a variety of marine sediment and environmental factors to yield information about a predicted outcome, in this case, susceptibility to slope failure. General strength-density relations can be used for modeling sediment accumulation and stability.

## **TRANSITIONS**

Geoacoustic properties are being used by mappers and acousticians to identify lithologies acoustically. Rheological properties are being used by modelers to represent debris flows. Landslide generation models are being used by landscape evolution modelers.

## **RELATED PROJECTS**

Lee has developed a USGS project to investigate sediment and pollutant transport on the Los Angeles margin using many of the same techniques produced by STRATAFORM. Locat is investigating the behavior of a newly formed sediment layer acting as a natural cap over contaminated sediment in Canada. The development of this project benefited from approaches developed within STRATAFORM.

## **PUBLICATIONS**

Boulanger, É., Locat, J., Desgagnés, P. Martin, F., and Lee, H., 1998. Geotechnical testing of Eel River sediments collected as part of the R/V Wecoma Cruise # W9807A (July 14 – 25<sup>th</sup> 1998). Department of Geology and Geological Engineering, Laval University, Québec, CANADA, GRECI Report 98-02, 45 p.

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